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California sea lions: Environmental impacts on population status and trend

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Terms of Reference Question

5. Analysis and modeling of ecosystem-level processes

Environment → California Sea Lion Survival & Population Status

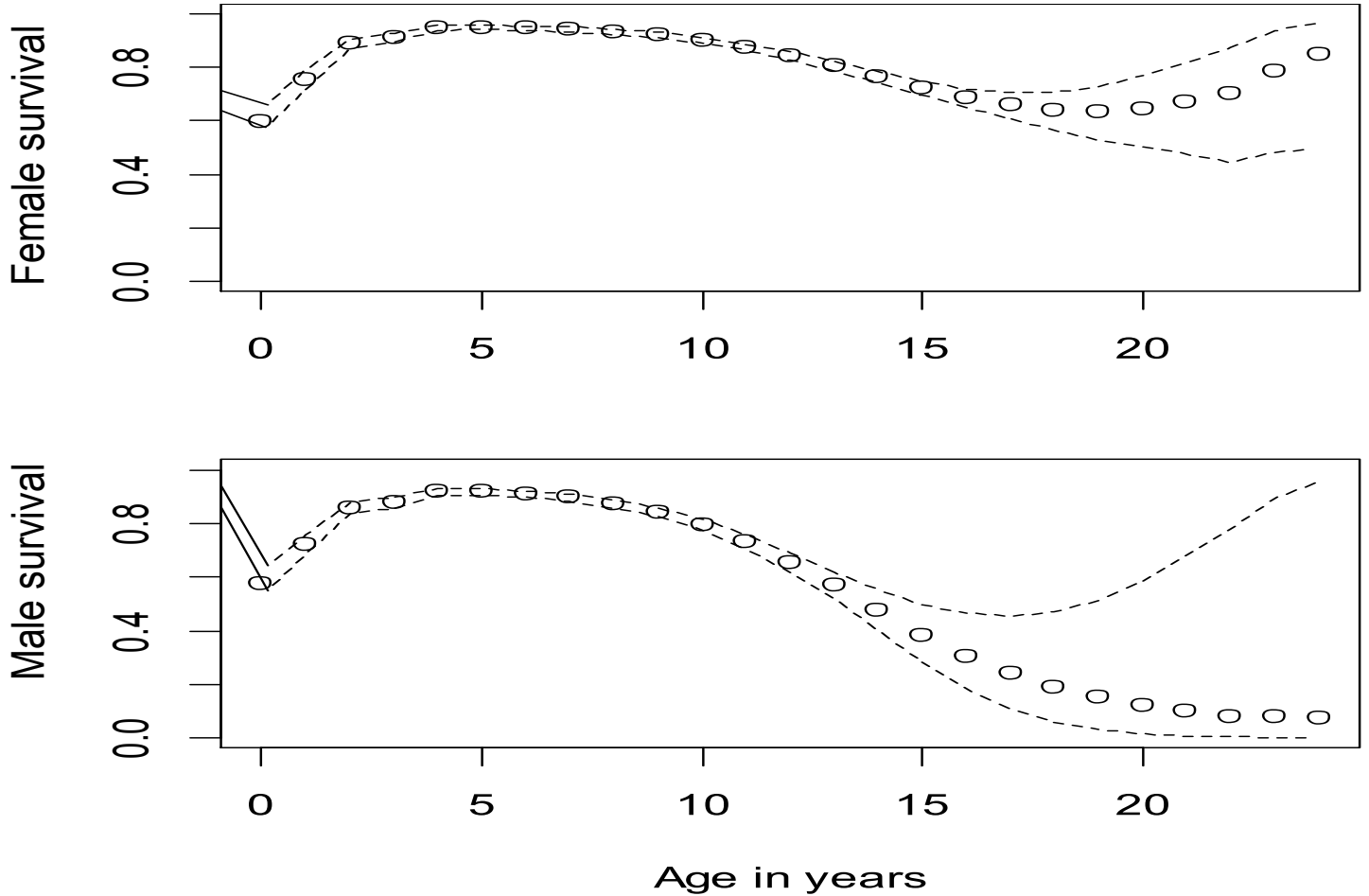
California Sea Lion Survival

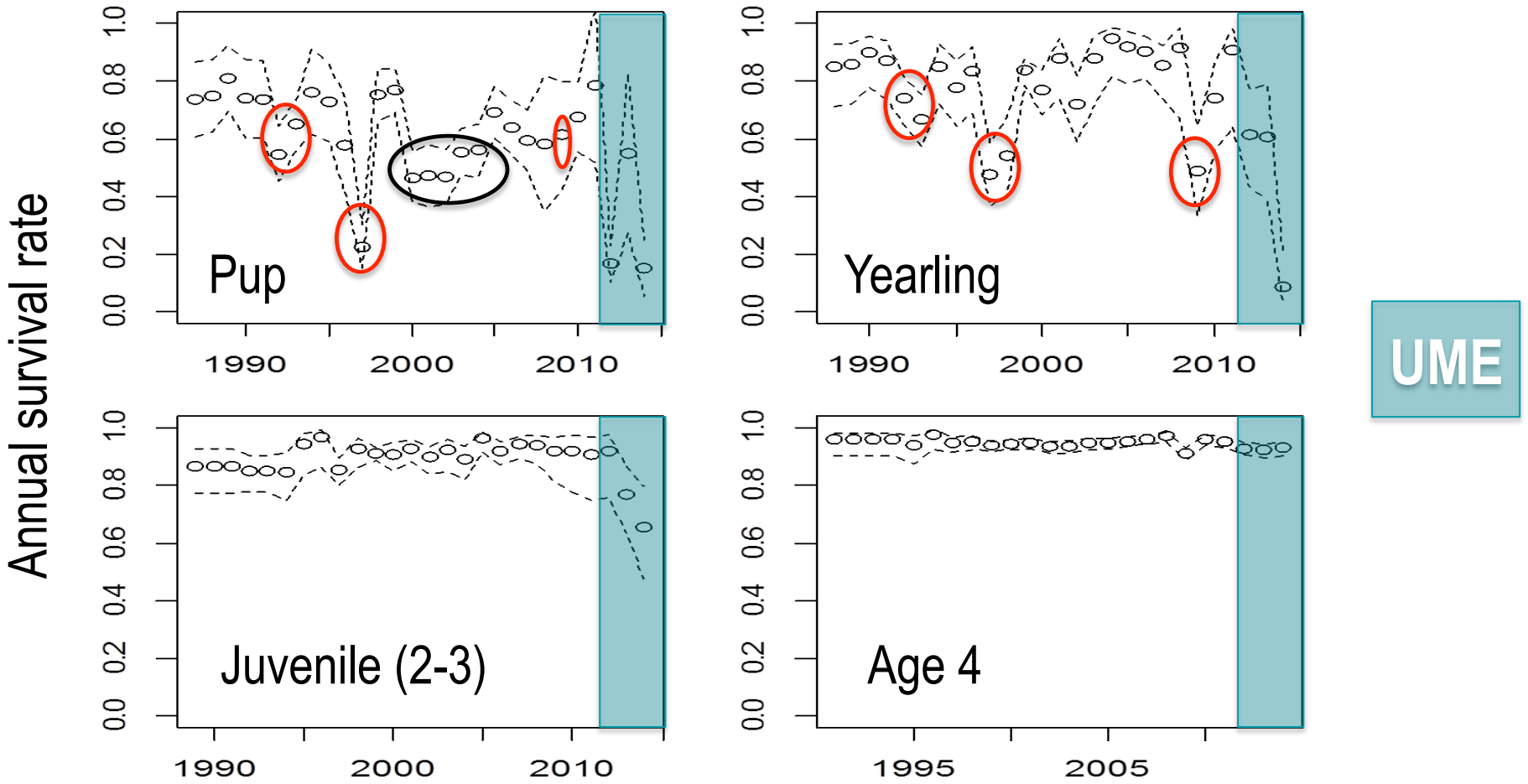
Data Collection

- A branding/tagging program has been conducted on San Miguel Island since 1987
- 200-500 pups have been weighed, marked with a unique number and released each year.
- Resighting has been conducted annually at San Miguel since 1990 and at Ano Nuevo since 1996.
- Reported dead recoveries have been recorded since 1987.

Survival Analysis

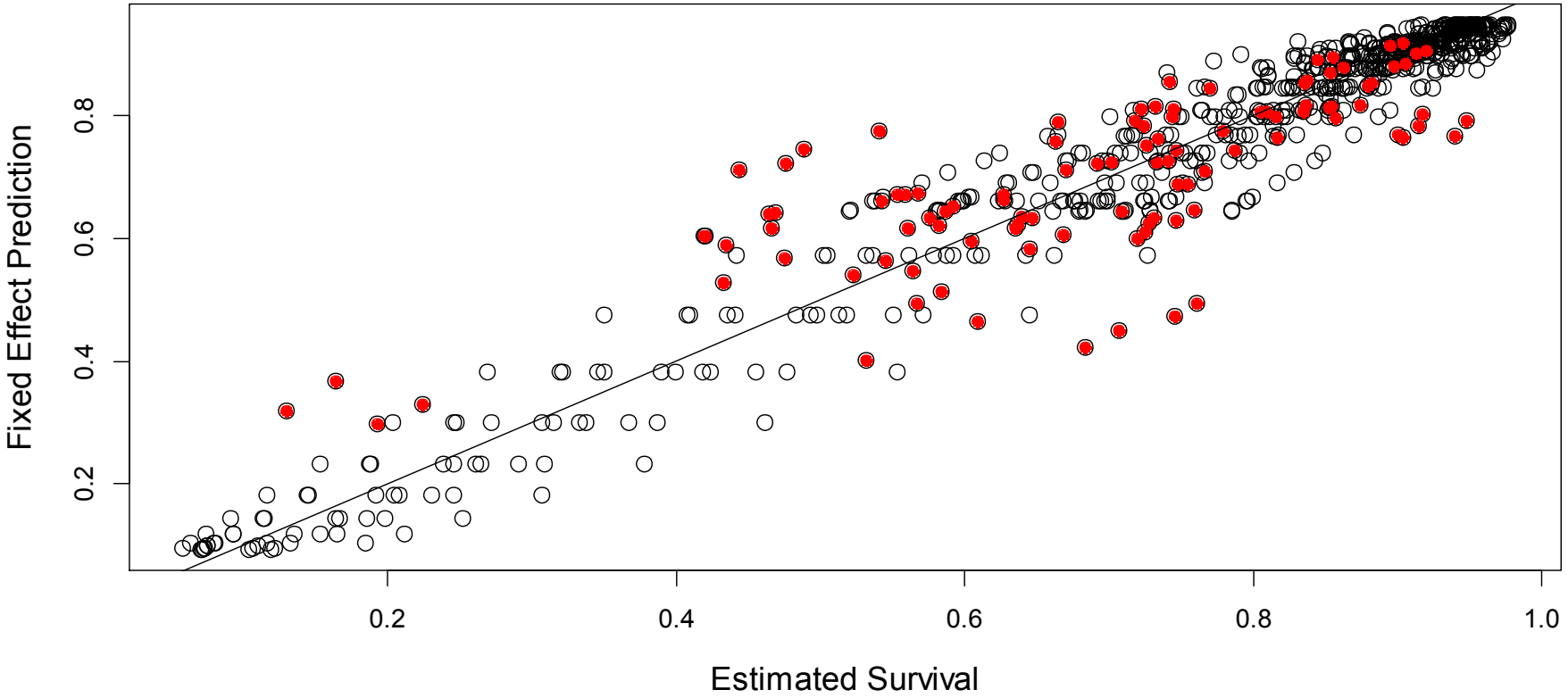
- Release-resight-recovery capture-recapture models were fitted to the encounter histories.
- Best fixed effect survival model included:
  - Age (cubic spline), sex and their interaction
  - Initial pup weight influencing pup and yearling survival
  - Annual variation in survival for pups, yearlings, ages 2&3 and for ages 4+


Female survival
0.0
0.4
0.8
0
5
10
15
20
Male survival
0.0
0.4
0.8
0
5
10
15
20
Age in years


Annual survival rate
Pup
Yearling
Juvenile (2-3)
Age 4
UME
0.0
0.2
0.4
0.6
0.8
1.0
1990
2000
2010
1995
2005

Survival Explanatory/Predictive Model

- Fit linear mixed effects model to sex- and age-specific survival estimates from 1987-2014.
- Fixed effects: average pup weight (+), sea surface temperature (-) and sea lion abundance (-). Differential effects with age.
- Random effects: annual variation for pups, yearlings, age 2+.

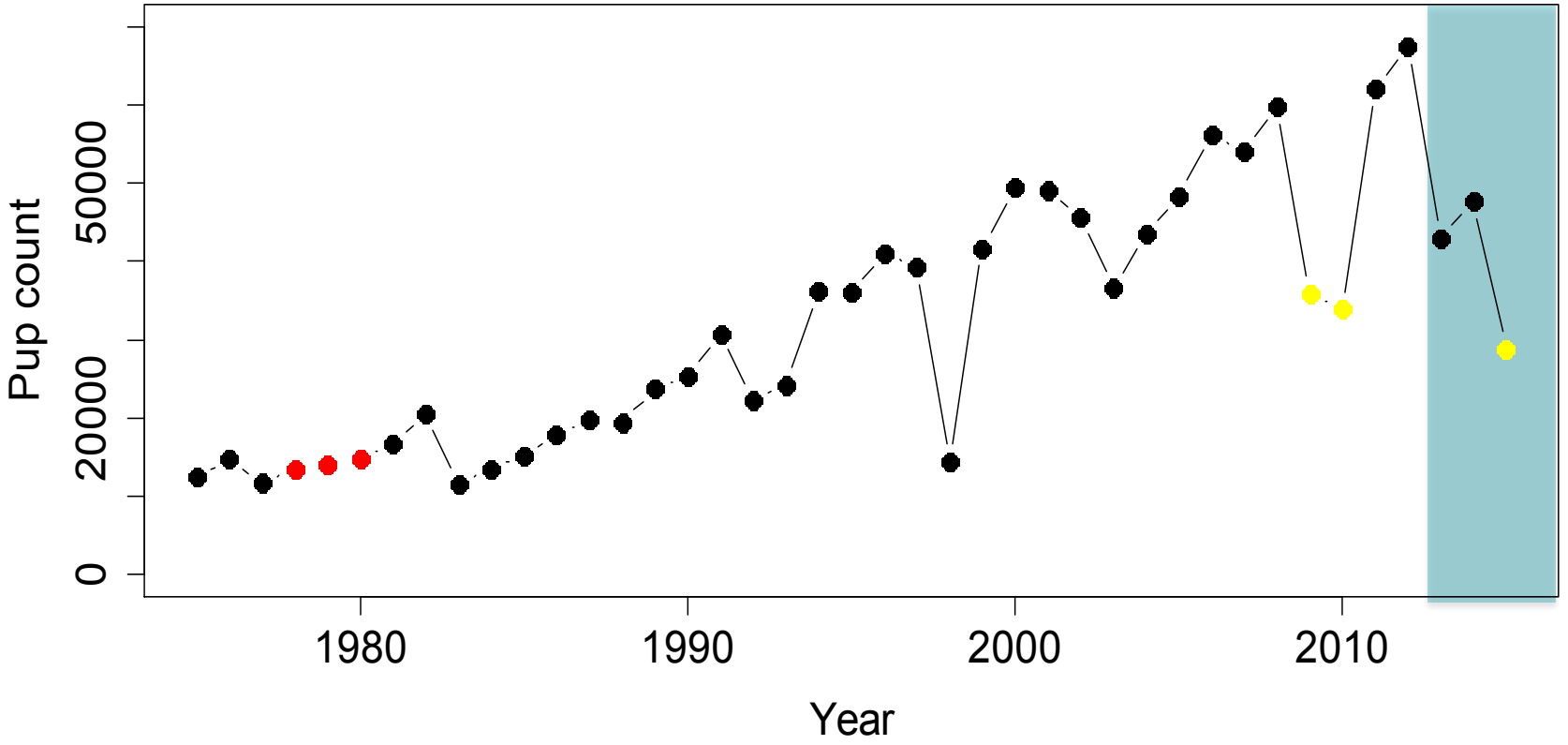

Fixed Effect Prediction
0.2
0.4
0.6
0.8
Estimated Survival
0.2
0.4
0.6
0.8
1.0

Survival Explanatory/Predictive Model

- From fitted model predict survival for each sex and age for 1975-2014 from annual pup weight and SST data and sea lion abundance estimate.
- Use survival predictions to reconstruct the population which is the next step. Iterate.

California Sea Lion Population Status

Sea Lion Pup Counts



Sea Lion Population Reconstruction

- Use total U.S. pup counts from 1975-2015 and survival estimates to reconstruct population.

$$N\downarrow a+1,y+1 = N\downarrow a,y \, S\downarrow a,y$$

$$3600 = 6000 \cdot 0.6$$

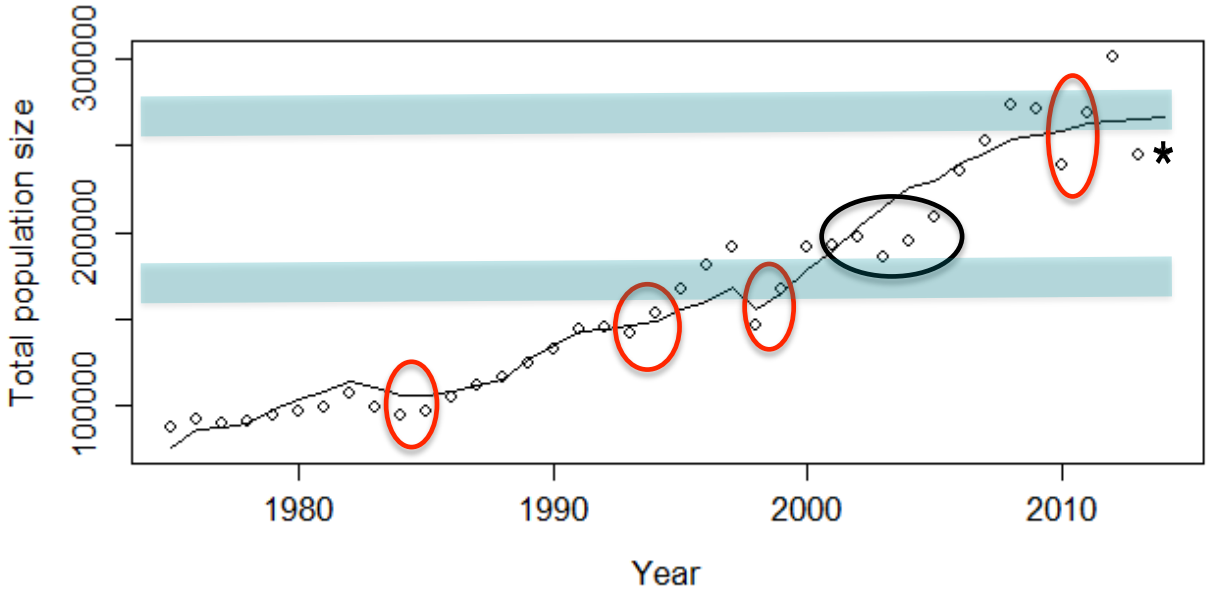
Sea Lion Population Reconstruction

Age	1975	1976	1977	1978	1979	…	2011	2012	2013	2014
0	$N_{0,1}$	$N_{0,1976}$	$N_{0,1977}$	$N_{0,1978}$	$N_{0,1979}$	…	$N_{0,2011}$	$N_{0,2012}$	$N_{0,2013}$	$N_{0,2014}$
1		$N_{1,1976}$	$N_{2,1977}$	$N_{3,1978}$						
2					$N_{4,1979}$					
3										
4										
…										
23	$N_{1,1975}$	$N_{1,1976}$	$N_{1,1977}$	$N_{1,1978}$	$N_{1,1979}$	…	$N_{2,2011}$	$N_{2,2012}$	$N_{2,2013}$	$N_{2,2014}$
24										
Total										

Population Status

- Fit generalized logistic growth difference equation with variable growth rate to annual total abundance.
  - $N\downarrow t+1 = N\downarrow t + N\downarrow t\,(R + b * SST\downarrow t)(1 - N\downarrow t\,/K)\uparrow z - H\downarrow t$
- From fitted model compute Maximum Net Productivity Level (i.e., population size yielding largest increase) and 2014 population status.
- A population which is larger than MNPL is said to be at its Optimum Sustainable Population (OSP) level.

Population Growth



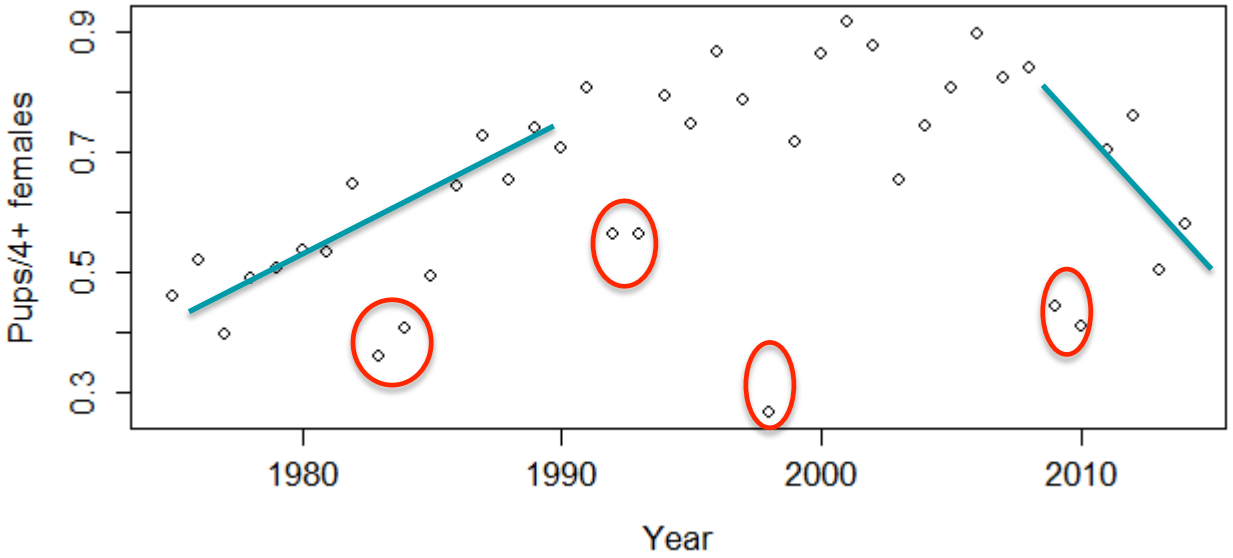
1) Population growth rate declines with increasing SST; +2 degree anomaly ~7% decline

2) Carrying capacity K= 250-280K

3) MNPL = 156-182K

4) 2014 population > MNPL. Official status to be determined after review process and publication.

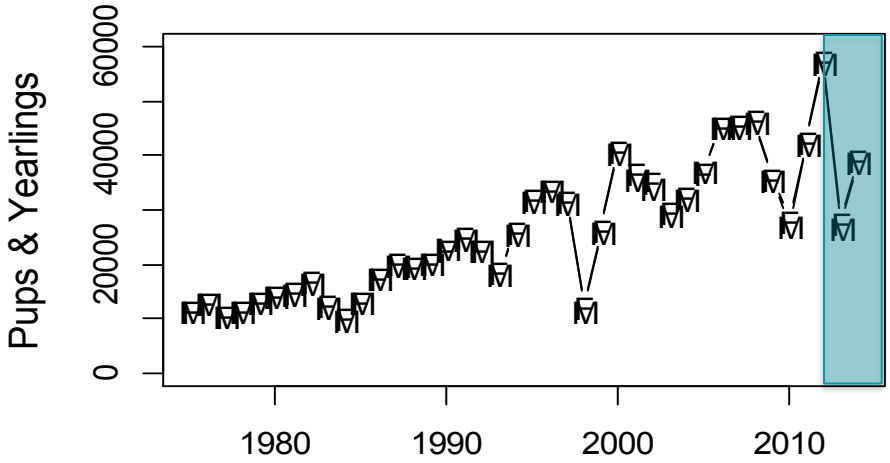
Realized Gross Birth Rate

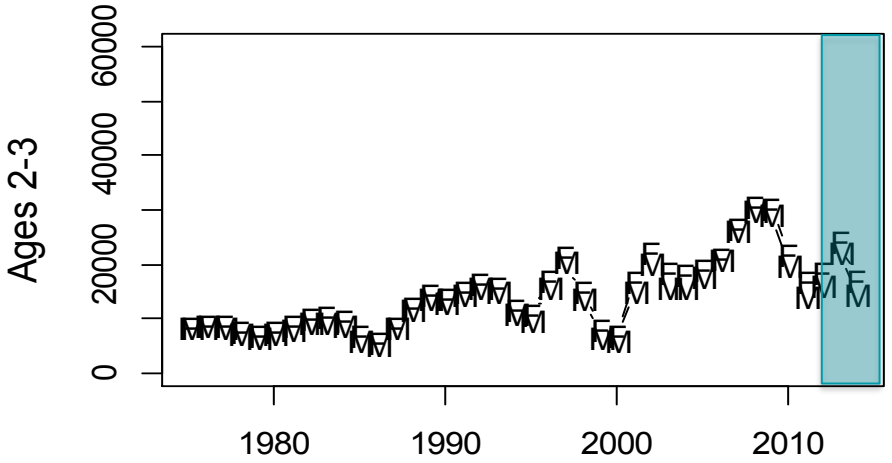


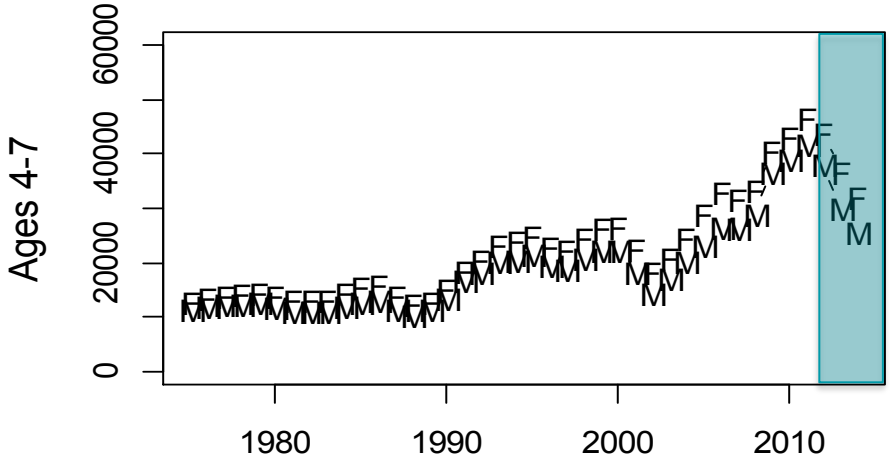
1) Birth rates increased initially as DDT contaminant levels decreased.

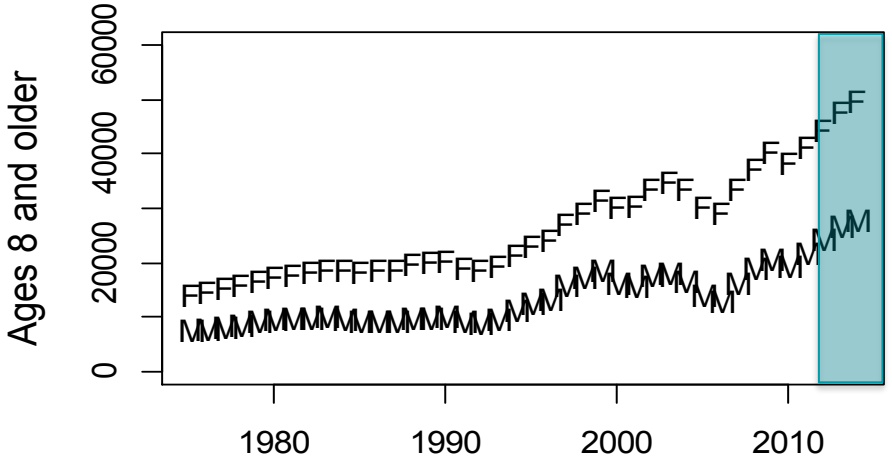
2) Birth rates declined with increasing SST.

3) Birth rates declined as population reached carrying capacity.


Pups & Yearlings
0
20000
40000
60000
1980
1990
2000
2010


Ages 2-3
0
20000
40000
60000
1980
1990
2000
2010


Ages 4-7
0
20000
40000
60000
1980
1990
2000
2010


Ages 8 and older
0
20000
40000
60000
1980
1990
2000
2010

Strengths, Challenges and Solutions

Strengths

- 4 decade time series
- Environmental linkage
- Sex-age trends

Challenges

- Maintaining long term data
- Incorporating prey data
- Island differences

Solutions

- Collaborative funding
- Fisheries biologists
- New model development